



International Journal of Doctoral Studies

An Official Publication
of the Informing Science Institute
InformingScience.org

IJDS.org

Volume 12, 2017

DESIGN-BASED RESEARCH IN DOCTORAL STUDIES: ADDING A NEW DIMENSION TO DOCTORAL RESEARCH

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ABSTRACT

Aim/Purpose	We show a new dimension to the process of using design-based research approach in doctoral dissertations.
Background	Design-based research is a long-term and concentrated approach to educational inquiry. It is often a recommendation that doctoral students should not attempt to adopt this approach for their doctoral dissertations. In this paper, we document two doctoral dissertations that used a design-based research approach in two different contexts.
Methodology	The study draws on a qualitative analysis of the methodological approaches of two doctoral dissertations through the lenses of Herrington, McKenney, Reeves and Oliver principles of design-based research approach.
Contribution	The findings of this study add a new dimension to using design-based research approach in doctoral dissertations in shorter-term and less intensive contexts.
Findings	The results of this study indicate that design-based research is not only an effective methodological approach in doctoral dissertations, but it also has the potential to guide future research direction beyond examination.
Recommendations for Practitioners	The findings of this study demonstrate that the design based research approach could bring researchers and practitioners together regarding a common purpose to design context-based solutions to educational problems.
Impact on Society	We show an alternative view and application of design-based research in doctoral dissertations. Also, we identify the benefits of this type of research for doctoral students after completing their dissertations.
Keywords	design based research, doctoral study, doctoral dissertation

Accepting Editor: Erik Shefsky | Received: November 17, 2016 | Revised: March 4, April 4, May 13, May 14, 2017 | Accepted: May 27, 2017.

Cite as: Goff, W. M., & Getenet, S.. (2017). Design based research in doctoral studies: Adding a new dimension to doctoral research. *International Journal of Doctoral Studies*, 12, 107-121. Retrieved from <http://www.informingscience.org/Publications/3761>

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INTRODUCTION

The fundamental assumption of empirical research, in most educational settings, is that practitioners will apply theories and research findings. However, we find that there is often no clear link between changes in practice and results of research (Corbin & Strauss, 2014). Design-Based Research (DBR) evolved near the beginning of the 21st century as a practical research methodology that provided a bridge between theory and practice in a classroom context (Anderson & Shattuck, 2012). It is complex and multi-faceted work that has the dual goal of developing theoretical insights and a solution to a problem (McKenney & Reeves, 2012). The dual goal of generating knowledge about both theory and practice simultaneously means that a close relationship with theory and new research findings is a crucial and ongoing component of the research process. DBR examines and develops theories about processes while also analyzing the effectiveness of a research design with participants, to shape the processes they are studying (Gravemeijer & Cobb, 2006). The recognition of the potential of DBR to advance theory and practice has seen the approach gain momentum in recent years, particularly in the field of education (van den Akker, Gravemeijer, McKenney, & Nieveen, 2006).

Barab and Squire (2004) define DBR as a series of approaches, with the aim of producing new theories and practices that potentially impact learning and teaching in naturalistic settings. This series of approaches has a label in many different terms, such as DBR (Kelly, 2006), development research (van den Akker, 1999), design research (Reeves, Herrington, & Oliver, 2005), developmental research (McKenney & van den Akker, 2005), and design experiments (Brown, 1992; Collins, 1992). It is often purported within the literature that DBR requires intensive and long-term collaboration between researchers and practitioners. This collaboration demands the development of solutions to practical problems in learning environments, with the identification of reusable design principles. This is a major driving force of the research. As a result, there is an assumption embedded within the educational field that DBR appears to be a long-term and intensive approach to educational inquiry. This assumption often projects the notion that doctoral student should not attempt to adopt this approach for their dissertations (Herrington, McKenney, Reeves, & Oliver, 2007).

However, some studies have begun to highlight the appropriateness of DBR for doctoral studies. Herrington et al. (2007) and Kennedy-Clark (2013) have illustrated the importance and the components of a dissertation proposal utilizing a DBR approach. For example, Kennedy-Clark (2013) suggested that the DBR approach can provide a platform for higher degree research (HDR) students to apply a range of analysis methods, data collection tools, and techniques that can lead to a better understanding of their study's relative strengths and weaknesses regarding these techniques. Herrington et al. (2007) provided specific guidelines on preparing the DBR proposal including a sequential and practical description of proposed research. Similarly, Plomp (2007) and Reeves (2006) have provided some insight to explicitly articulate the differing phases of a DBR approach, making it easier for doctoral students to conceptualize the approach in action. However, there is still a limited amount of research on how to use the DBR approach, particularly in HDR or doctoral studies contexts (Kennedy-Clark, 2013).

This study's authors illustrate the practical use of DBR in two doctoral dissertations. The two dissertations designs revolve around the notion of professional development and each formulated a set of draft principles to guide educators involved in supporting the mathematical learning of children. Also, we illustrate the challenges of using the DBR approach during the research process of the two doctoral studies and highlight how this approach can effectively utilize and adapt to doctoral dissertations. Our research question is, "How can researchers use DBR to approach different doctoral dissertations and other short term, less intensive, research contexts?"

LITERATURE REVIEW

DBR is a research approach that extends existing methods to address the issue of linking theory and practice in educational research (Corbin & Strauss, 2014). Within the DBR process, researchers ac-

tively frame problems to improve a perceived or current situation or problem. Kennedy-Clark (2013) considered DBR as a constructivist-based proposition of an alternative epistemology of practice and presented as a thoughtful conversation with the situation. In addition, it is a methodological approach grounded in a pragmatic epistemology. Pragmatists rejected the quest for certainty, suggesting that science becomes understandable when the conception of science as a system of absolute truths is dropped (Maxcy, 2003) and the existence of multiple subjective realities is appreciated (Tashakkori & Teddie, 2010).

Pragmatism is a generative mode of inquiry that is concerned with lived experience and interpretation. In fact, lived experience is at the forefront of pragmatic inquiry where the study participants are not subjects of a study, but are experts and knowledgeable participants within their communities (Metcalf, 2008). At the core of the inquiry is a path into reality (Cobb, 2011). Therefore, an inquiry is not only practical and outcome-orientated, but also scientific and should be entwined with, and lead to, developing new theoretical understandings (Johnson, Onwuegbuzie, & Turner, 2007).

The pragmatic inquiry does not prescribe how an inquiry should take place, but the pragmatic nature of the inquiry supports to reason out how the choices were made throughout the inquiry (Cobb, 2011). It is through this argument that new theoretical considerations emerge to examine, refine, and develop existing theoretical understandings. DBR provides a vehicle for pragmatic inquiry, through a series of methodological approaches to assist in the exploration of complex phenomena in real-life contexts and in collaboration with people engaged in everyday practice (Herrington et al., 2007). This series of approaches works simultaneously to improve practice, while also testing, refining, and developing a scientific practice (Barab & Squire, 2004). The following two sections describe phases of DBR mapped against typical elements of a HDR proposal and model the use DBR in doctoral studies.

DESIGN BASED RESEARCH IN HIGHER DEGREE RESEARCH

In HDR study, the development of the research proposal is an integral part of the doctoral process. If done well, the research proposal provides the HDR student with a robust plan to implement. It also provides a reliable map for referring to as the candidature unfolds. Most universities tend to provide their HDR students with specific guidelines to follow to prepare the research proposal (Herrington et al., 2007). There are some variances between the requirements of different institutions and disciplines areas to prepare the research proposal. However, typical guidelines generally include information about the development of aims and objectives, rationale, research questions, significance, literature review, theoretical framework, methodology, data collection and data analysis, timeline, and ethical considerations (e.g., Herrington et al., 2007; Kennedy-Clark, 2013).

University guidelines provide HDR students with some sound insight into developing a plan for conducting traditional research. However, if the conceptualized inquiry does not fit neatly into the traditional research design, guidelines provided by universities for doctoral students are confusing rather than helpful when formulating the research proposal and conduct the inquiry (Herrington et al., 2007). Herrington and colleagues provided insight into this issue by outlining how HDR students adopting a DBR approach might formulate a DBR project within a traditional, predictive doctoral research proposal. To do this, they present four phases of DBR by breaking down the preliminary phase of the approach into two separate phases. The phases of DBR are then juxtaposed with the elements of a traditional and predictive research proposal to demonstrate 'fit.' Table 1 highlights this mapping, as illustrated by Herrington et al. (2007).

While the work of Herrington and colleagues (2007) has been helpful in demonstrating how DBR might fit within the traditional research proposal, it does not adequately highlight the strength of DBR in HDR work, nor does it show the versatility and flexibility of the approach in conducting the research inquiry. It is important for both HDR students and their supervisors to realize the potential and strength of the DBR approach to obtain a sound basis for research *training*.

Table 1. Design-based research and elements of a research proposal

PHASE OF DESIGN-BASED RESEARCH (REEVES, 2006)	THE TOPICS/ELEMENTS THAT NEED DESCRIPTION	POSITION IN A RESEARCH PROPOSAL
PHASE 1: Analysis of practical problems by researchers and practitioners in collaboration	Statement of problem	Statement of problem or Introduction or Rationale or Background
	Consultation with researchers and practitioners	
	Research questions	Research questions
	Literature review	Literature review
PHASE 2: Development of solutions informed by existing design principles and technological innovations	Theoretical framework	Theoretical framework
	Development of draft principles to guide the design of the intervention	
	Description of proposed intervention	Methodology
PHASE 3: Iterative cycles of testing and refinement of solutions in practice	Implementation of intervention (First iteration)	Methodology
	Participants	
	Data collection	
	Data analysis	
	Implementation of intervention	
	Second and further iterations	
	Participants	
	Data collection	
	Data analysis	
PHASE 4: Reflection to produce “design principles” and enhance solution implementation	Design principles Designed artefact(s) Professional development	Methodology

MODELS TO USE DESIGN-BASED RESEARCH IN DOCTORAL STUDIES

Abdallah and Wegerif (2014) highlight the flexibility of DBR by presenting a version of DBR for doctoral studies. In contrast to the guidance provided to doctoral students by Herrington and colleagues (2007), the model does not provide a particular format in which to follow but rather “flexibly outlines realistic methods and procedures followed in the study under the DBR umbrella” (Abdallah & Wegerif, 2014, p.15).

Derived from the work of Plomp (2009) the model presented by Abdullah and Wegerif (2014) is structured around three specific phases;

1. Integrating literature and exploratory research to develop initial theoretical framework for design,
2. Implementing this with careful evaluation of processes as well as products in two iterations, using the results of the study of the first iteration to refine the second iteration, and
3. Finally using the results of the second iteration to produce a new and improved theoretical framework for design ready for further research study presented as the main outcome of the thesis.

The authors suggest that this model highlights the flexibility of DBR by incorporating the notion that the particular context, nature, and objectives of individual research inquiries are unique (Abdallah & Wegerif, 2014). However, in doctoral research, the model is too broad, and as a result, lacks the specific guidance needed to navigate the different stages of the doctoral process.

Kennedy-Clark (2013) provides an overview of DBR in the HDR experience and contextualize the phases of DBR in doctoral studies. In a comparison of doctoral theses using DBR, Kennedy-Clark suggests that the three phases of DBR can provide enabling checkpoints that support HDR students in redefining and reflecting on their research as it progresses. In the following section, we have illustrated the three phases of DBR, which are the preliminary phase, the prototyping phase, and the assessment phase.

Doctoral students consider the preliminary phase as the stage of the inquiry to formulate the investigation and prepare the research proposal. This stage incorporates the doctoral proposal and all of the typical requirements that the proposal requires (review of literature, conceptual framework, research questions formulation, etc.).

According to Kennedy-Clark (2013), the next phase of the approach is the prototyping phase, which marks the commencement of the research. This phase also involves a number of iterations of an intervention or material, with each iteration being a micro cycle of the research. The final phase posited is the assessment phase. Kennedy-Clark suggests that the purpose at this stage of the inquiry is to conclude the inquiry by discussing how the investigation has answered the research questions. While the checkpoints provided by Kennedy-Clark provide some more specified direction as to how doctoral students might use DBR in the doctoral process, they provide little insight into the flexibility of DBR as a pragmatic mode of inquiry.

The DBR models discussed make a vital contribution to the field of DBR and provide some guidance concerning the HDR candidature. However, more insight and guidance into the flexibility of DBR for doctoral research is needed to ensure that students and their supervisors understand the potential afforded through the DBR approach. Notably, understanding the challenges of using DBR in doctoral studies paves the way to its effective use in doctoral work. Anderson and Shattuck (2012) advise that one of the challenges for doctoral supervisors and their students in the uptake of a DBR approach lies in the requirement of multiple iterations juxtaposed alongside the time restraint of the HDR candidature. They further suggest that a partial solution is for established education researchers to develop multiyear DBR research agendas that have legitimate space and roles for graduate students to undertake and *own* significant pieces of this larger agenda (Anderson & Shattuck, 2012). While such solution might be a viable way to assist doctoral supervisors and students in realizing the potential of the approach in doctoral work, it requires significant monetary and time investment that might not necessarily be afforded in educational research.

Others also indicate various challenges of the methodological approach that might be problematic for doctoral students. These challenges include issues around research data usage, the problem of objectivity, involving participants in the research process, and the time to complete the research process in its entirety (Dede, 2004; Design-Based Research Collective, 2003; Wang & Hannafin, 2005). Studies have also indicated that DBR researchers are often finding themselves playing the conflicting

roles of advocate and critic (Design-Based Research Collectives, 2003) which can be a difficult path for the novice researcher to navigate.

Despite the challenges, DBR can be drawn upon for a variety of purposes. For example, Thein, Barbas, Carnevali, Fox, Mahoney, and Vensel (2012) used DBR to investigate the effectiveness of teaching multicultural literature through a collaborative and iterative process of inquiry guided by theoretical principles. Hakkarainen (2009) showed its applicability in education to design, implement, and refine a problem-based learning course on educational digital video use and production. Similarly, Wang and Hannafin (2005) showed the effectiveness of the DBR approach to design technology-enhanced learning environments. Each of the studies was iterative, but their duration of iteration varied across the different approaches. This is important insight for doctoral students as it highlights the adaptability of the approach for different purposes.

METHOD

In this study, we examine the methodological approach of two doctoral dissertations against the phases and principles of the DBR through a qualitative comparative descriptive approach. Table 1 shows the phases and principles of the DBR suggested by Reeves (2006) and Herrington et al. (2007). The study also identifies the purposes, brief outcomes, and the challenges of each doctoral study and demonstrates how the approach can be effectively adopted and modified to suit the doctoral inquiry.

DATA ANALYSIS

The authors of this study analyzed the data from both doctoral studies alongside with the different phases and principles of the DBR approach. The analysis involved identifying themes and actions that were evident across both studies within each of the DBR phases and principles. After the authors identified the themes, the two studies were re-analyzed to identify common challenges that were evident across each of the inquiries. In the later section, we then examined the data alongside with the traditional doctoral process to establish a set of principles to guide doctoral work that draws on a DBR methodological approach.

BACKGROUND INFORMATION - THE TWO DOCTORAL STUDIES' PURPOSE AND CONTEXT

Doctoral study 1: Tertiary level

In doctoral study 1 [DS1] (Getenet, 2015), DBR was used to design a Professional Development (PD) program and simultaneously study the research participants' knowledge of technology integrated mathematics teaching. Hence, in DS1, the analysis of a learning problem formulated the research proposal and prompted quite specific ideas for a PD program approach. Alongside the PD program, the researcher included the creation of particular teaching and learning materials and methods designed to realize participants' learning gains predicted by theory and research. The section below illustrates the activities conducted in DS1 in each phase.

The preliminary phase of the research involved a contextual and problem analysis of teachers' knowledge of technology integrated mathematics teaching, with the development of a conceptual framework based on a review of the research literature. During this phase of the study, the researcher reviewed the theoretical framework of the study and formulated the PD program guidelines. The guidelines included the formation of teams, identification of available ICT, and the consideration of web-based software. Developing the theoretical framework for the study involved a review of the relevant literature to frame the knowledge required of mathematics teacher educators to integrate technology into their teaching. It also involved the development of an associated instrument to measure mathematics teachers' knowledge of technology-integrated teaching in mathematics. The researcher used Smith and Ragan's (2005) categories of context to drive the PD program guidelines

through a context analysis. These categories are the analysis of learning context, analysis of learners, and analysis of learning tasks.

The second phase of DS1 focused on setting out design guidelines and optimizing the planned PD program through cycles of design, evaluation, and revision (Kelly, 2006; Plomp, 2009). This phase of the study was iterative, with formative assessment aimed at improving the intervention. Assessing the quality of the PD program in terms of its practicality and validity was part of this phase. Participants in DS1 were actively involved in shaping each PD program guideline for possible improvement. The participants further recommended additional PD program guidelines that made the intervention more relevant to their contexts. For example, they suggested the formation of small teams based on their work arrangements.

The last phase of the study was a summative evaluation to determine the extent to which the PD program had met the pre-determined objectives. This phase resulted in recommendations for improvement to the PD program. This phase also assisted to identify the effectiveness of the PD program. It involved examining the impact of the PD program on the research participants' technology integrated mathematics teaching practices by comparing before and after results of participation. In this phase, presenting samples of lessons supported to show the effectiveness of teacher educators' ICT integrated mathematics teaching.

In summary, DS1 drew upon DBR to improve practices. As such, the DBR followed in DS1 was helpful for teachers to meet the learning needs of their students. It also provided a voice to practitioners in the research process.

Doctoral study 2: Transition into the first-year-of-school

DBR was used in doctoral study 2 [DS2] (Goff, 2016) to formulate a set of draft principles to guide educators and researchers involved in supporting the mathematical learning of children making the transition to school. The research proposal included the analysis of a problem that the researcher had experienced personally, and in her role as both a first-year-of-school and prior-to-school teacher. The problem centered on how to best support the current mathematical understandings, skills, and knowledge of children when they start formal education. The research proposal included a theoretical analysis of the problem, coupled with a proposed solution (intervention) and given to practitioners for further refinement and implementation. The purpose of the study was not to test the effectiveness of the proposed intervention, but to draw on the refinement and implementation of the intervention in context, to develop some draft principles for future work in this area. The section below illustrates each phase of DBR as reflected in DS2.

The preliminary phase of the study involved establishing a sound theoretical construct. The development of the theoretical construct focused on how the mathematical learning of children best be supported during the transition to school. Once established, the theoretical construct was then drawn upon to develop a tentative research plan: an intervention that focused on supporting the mathematical learning of children. In relation to the development of the research proposal, the researcher presented a tentative plan for the research, but she communicated in her candidature document that the study was emergent, and therefore how it unfolded in practice could not be predetermined.

After confirmation of candidature, the researcher took the research proposal to practitioners for discussion and refinement. It was at this stage of DS2 (Phase 2) where the researcher recruited participants into the study and primed the intervention for implementation in two different contexts. The researcher documented both Phase 1 and Phase 2, which formed a significant component of the final thesis document. The refined intervention involved the establishment of two research teams located at two different sites (consisting of a prior-to-school and first-year-of-school teacher and families of children making the transition to school). Each research team was provided with the design-brief to create a plan that would support the existing mathematical understandings of children as

they made the transition to school. The researchers' role within the project was to study what transpired at the two different sites.

The third phase of DS2 involved implementing the refined intervention. As the implementation took place, four research team meetings were conducted at each of the two sites. Research team meetings provided an opportunity for participants to talk about their experiences, including some of the challenges and opportunities that were transpiring. They also provided an opportunity for further refinement of the intervention as it unfolded in practice, and afforded the researcher and participants with various opportunities to guide or 'test-out' the intervention in different ways. During this phase, the researcher documented the processes as the intervention unfolded at the two different sites. This included the documentation and 'on-the-run' analyses of all decisions.

The final phase of the project involved a retrospective analysis of the process from conception to completion. In this phase of DS2, the conceptual framework of the Cultural Interface (Nakata, 2007) was drawn upon to analyze what transpired in practice. The purpose of this retrospective analysis was not to test the effectiveness of the intervention but to derive a set of draft principles that could be further refined and drawn upon in later work. In the thesis, these principles were presented as a starting point for others embarking on similar work (Goff, 2016). The final phase also involved examining the draft principles alongside current research literature. This facilitated a way to provide recommendations for utilizing the draft principles and suggested their application for future work.

The findings of DS2 resulted in six design principles. These results are not definitive but rather provide a starting point for those examining how best to support the mathematical learning of children making the transition to school. They also provide a research trajectory for the doctoral student (Goff, 2016) post candidature. The six design principles are focused on how adults come together to support the mathematical learning of children and provide insight into what might need to be considered by those embarking on similar work. The six principles are:

Principle 1 - The transition to school is recognized as a developmental context for adults.

Principle 2 - Relationship and partnership are recognized as independent but interconnected concepts.

Principle 3 - Adults are supported to navigate through their transition experience.

Principle 4 - A particular task to perform will provide a reason for ongoing interaction and facilitate partnership.

Principle 5 - Opportunities for ongoing interactions about mathematics are afforded and

Principle 6 - Opportunities to reconstruct mathematics in a shared space are provided (Goff, 2016).

RESULTS

In this section, we present the results of the study by examining the methodological approaches of the two doctoral dissertations against the phases and principles of DBR. The results focus on the phases of DBR and the challenges in using the DBR approach as reflected in the two doctoral studies.

PHASES OF DBR IN THE TWO DOCTORAL STUDIES

In the two doctoral studies, each phase of the DBR approach was used to fit their purpose. For example, DS1 used the first phase to develop a PD program and conducts a contextual analysis, whereas DS2 used this phase to investigate a problem of practice and develop a solution to the problem.

Table 2 presents activities in each of the doctoral studies and the themes that emerged across the two studies. The background information of the two doctoral studies described in the method section of this study supported to identify the themes described in Table 2.

Table 2. Summary of themes emerged alongside the phases of the DBR Approach

PHASES	ACTIVITIES IN EACH PHASE		THEMES AND ACTIONS
	DOCTORAL STUDY 1	DOCTORAL STUDY 2	
Phase 1	Researcher develops PD program and conducts a contextual analysis. Participants are recruited into the project.	Researcher investigates a problem of practice and develops a proposed solution (intervention).	<ul style="list-style-type: none"> Contextual analysis Back-ground/Groundwork Formulation of the research project
Phase 2	Design guidelines are established, and the PD program is implemented. The PD program is refined with practitioners in real-world contexts through several iterations of redesign and implementation.	The problem of practice and the proposed solution is presented to participants for further investigation and refinement. Participants recruited into the project.	<ul style="list-style-type: none"> Implementation of Research Project Data Collection Ongoing Analysis and Refinement
Phase 3	A summative evaluation of the PD program is conducted.	The intervention is implemented and further refined with participants in real-world contexts. The researcher documents and guides this process alongside participants through iterative cycles of refinement.	<ul style="list-style-type: none"> Evaluation
Phase 4	Design principles for the PD program are derived and presented.	Retrospective analysis and the development of draft principles.	<ul style="list-style-type: none"> Formulation of Design Principles

As shown in Table 2, even though both doctoral studies have completed similar activities in Phases 1, 3 and 4, the activities completed in Phase 2 were slightly different. For example, the primary focus of DS1 in Phase 2 was designing PD program guidelines and refinement of the PD guidelines working with practitioners in real-world contexts. Whereas, the focus of DS2 in Phase 2 was presenting a proposed solution to participants for further investigation and refinement as well as participants' recruitment.

CHALLENGES IN CONDUCTING EACH DOCTORAL STUDY

Doctoral study 1

DS1 encountered a number of challenges. The challenges in DS1 included an extensive data set, challenges with how the researcher might position himself as the study unfolded, collaborating with research participants in the research process, and the time constraint to complete the research project. In the following paragraphs, we illustrate each of the challenges in DS1.

In DS1, the use of multiple instruments and multiple data sources generated a significant amount of data. The data collection instruments were questionnaires, interviews, observations, and focus group

discussions (including workshops). As a result, the researcher made a choice regarding aspects of the research to emphasize and selecting the data that addressed the research themes as encapsulated in the research questions. This did not mean that the doctoral study used a small part of the data collected. Rather, it documented the whole design process and reported key findings.

The second challenge in DS1 was the role of the researcher, either towards the subjective side or towards closer to an objectivist stance in the research process. However, the researcher played a significant and positive role in shaping the phenomena under study. As a result, in DS1, the researcher engaged in creative activities of developing PD program guidelines guided by existing scientific knowledge and practitioners' voice. Equally, the researcher was careful not to impose the values and beliefs held but acted as a facilitator throughout the process.

Deeply involving participants in the research process was another challenge identified in DS1. At the start of DS1, the participants in the study preferred to attach themselves to the matured teaching practiced approaches rather than immersing themselves in a new approach, which required the use of ICT in their teaching. It took a significant time investment to engage effectively the participants in each activity of the research process.

DBR usually takes an extended period so that a PD program can be developed and refined through an iterative process and as a result have a maximum impact on the participants' practices (Wang & Hannafin, 2005). Due to the restricted time frame of the doctoral candidature, the study was unable to incorporate multiple prototypes for the PD design (Getenet, 2015).

Doctoral Study 2

In DS2 (Goff, 2016) similar challenges were encountered. These challenges included decisions around the recruitment of participants, the large data set that emerged, and the time constraints imposed by the doctoral process. The recruitment of participants in DS2 was an intricate process that demanded a significant component of planning. The close proximity in which the researcher works with participants in DBR necessitates that a sound rapport between researcher and participant is developed (Mitchell, 2010). Within the time restraints of the doctoral process, this required careful consideration and various purposeful steps. For example, the researcher initially met with the participants' supervisors (the school principal and the pre-school coordinator) to explain the project and detail the level of support afforded to the participants. Such steps were planned during the proposal stage of the research and were designed to maximize the time that could be spent developing and building rapport.

Similarly, to DS1, the use of multiple instruments (video-recorded team meetings, research field notes, participant diaries, and email data) and data sources generated a significant amount of data. As a result, choices had to be made about which aspects of the data collected were to be highlighted and emphasized. The researcher chose the relevant data by maintaining an explicit focus on the research questions under investigation, rather than opening the inquiry up to other possibilities that emerged as the investigation unfolded. Table 3 summarizes the challenges identified in DS1 and DS2.

Table 3. Challenges identified in each doctoral studies

CHALLENGES IDENTIFIED	DOCTORAL STUDY 1	DOCTORAL STUDY 2
Recruitment of participants	-	Yes
Data usage/Large data set	Yes	Yes
Objectivity	Yes	-
Creating collaboration	Yes	-
Time constraint	Yes	Yes

As shown in Table 3, we have identified that recruitment of participants, large data sets, and time constraints were the challenges in both doctoral studies. For example, in relation to time constraint, it is assumed that DBR inquiries are typically in-depth and longitudinal, and involve a research team rather than a solitary researcher. In the two doctoral studies, however, such affordances were not present due to the nature of the doctoral candidature and the limited time the doctoral process imposes. To combat these issues, the researcher (in DS2) considered the inquiry beyond the doctoral process. As such, the DBR process was broken down into two distinct components – the doctoral research and a post-doctoral plan. This resulted in a change of purpose of the doctoral research, whereby the aim of the inquiry was to formulate a draft set of design principles that could be both offered to others as a starting point for engaging in similar work and a starting point for post-doctoral studies. In doing so, the nature of depth of the DBR approach was not lost through the time constraints imposed by the doctoral candidature, nor was the notion that DBR demands an investment in time if it is to generate long-lasting or significant change. Table 4 summarizes the principles for a doctoral dissertation, potential challenges as reflected in both doctoral studies and possible actions to overcome those challenges.

Table 4. Principles for DBR in Doctoral Studies

PHASE	PRINCIPLES FOR DOCTORAL WORK	POTENTIAL CHALLENGES	ACTIONS
1	Formulation of the Research Proposal	Creating Collaboration Time Constraint	Contextual Analysis and Formulation of the Research Project
2	Implementation of the Research Project	Requirement of Participants Large Data Set Generated Objectivity	Data Collection and Ongoing Analysis Focus on the research questions under investigations Carefully define the researcher's role where to influencing and shaping the phenomena under study
3	Summative Analysis of Data Formulation of Design Principles	Large Data Set Data Usage Time Constraints	Evaluating the project Answering the research questions
4	Thesis finalized	Time Constraints	Retrospective Analysis of the entire project

Formulating a plan that extended beyond the doctoral inquiry also provided the researcher with a trajectory for academic work beyond candidature. This is an important consideration for doctoral candidates to formulate a career in academia.

In summary, both doctoral studies encountered similar challenges in using DBR as a methodological approach.

DISCUSSION

The two doctoral studies transpired in different contexts; however, they remained consistent with using the DBR methodological approach. Both doctoral projects were aligned directly with the vari-

ous phases and principles proposed by Reeves (2006) and Herrington et al. (2007). However, the overall goal of methodology for each of the projects was what differed. The goal of the method for DS1 was to formulate a set of design principles and complete the DBR process. Whereas, the goal of DS2 was to commence the DBR process by developing a set of draft principles that could be further refined, tested, and built upon post-candidature. Goals of the methodology are an important consideration when navigating the doctoral process, particularly if doctoral students considered DBR as the methodological approach adopted. Thinking about the doctoral process in different ways such as the beginning of a longitudinal inquiry can facilitate this notion. Consistent with the recommendations of Anderson and Shattuck (2012), in this study, the authors noted that the doctoral students remain focused on the goals that they set out to achieve rather than becoming caught up in the iterative and emergent nature of the DBR approach. This implies that the methodology should support the research goals rather than create them.

In each doctoral study, the DBR methodological approach provided a solid basis from which to engage in educational inquiry. Each study was situated in the pragmatics of the everyday, was conducted in collaboration with practitioners, and was emergent in nature. The DBR principles were used to satisfy each doctoral study goal working with practitioners. Both doctoral studies were also interventionist and were designed to address a problem of practice. Identifying similarities across different inquiries that have adopted a DBR methodological approach provides a basis that other doctoral candidates can draw upon. The two doctoral studies presented in this paper, coupled with the various phases and activities presented by Reeves (2006) and Herrington et al. (2007), provides insight into this process.

Mapping the themes that emerged across the two doctoral approaches, alongside the traditional doctoral research approach, highlights the effectiveness and flexibility of DBR as an appropriate methodology for doctoral work. Explicating the different stages of the doctoral candidature provides a robust roadmap in which HDR students can align the specific milestones of their candidature alongside the various phases of the approach. It also provides a roadmap for HDR supervisors as they guide and support their students' candidature.

The design principles for doctoral work highlight the different stages of doctoral work alongside the various phases of the DBR approach. The actions and potential challenges presented provide insight into what activity should take place throughout the candidature as well as highlight the differing challenges that the HDR student might face as the study unfolds.

The challenges that emerged in the doctoral studies presented in this study were not unlike those challenges identified by others within the DBR research literature (see Anderson & Shattuck, 2012; Dede, 2004). Creating complex interventions with practitioners in real-world contexts is a challenging activity. Researching and driving the research process adds to this complexity, particularly within the doctoral candidature where the added pressures of the limitation of time and the novice navigation of the research terrain are also present. To overcome some of these challenges, it is important that the doctoral candidate makes use of the human resources that surround them at this time – particularly experienced researchers and supervisors who are well-positioned to provide guidance and mentorship. Maintaining a close relationship and focus on the research questions under investigations will also achieve this goal (see Table 4), as will a preparedness for the common challenges identified in this study. In the two doctoral studies, time constraint was overcome through, for example, owning the significant pieces of the larger research agenda, which are consistent with the recommendation of Anderson and Shattuck (2012).

Different from the common trends of educational research, which is its emphasis on practices rather than a focus to improve practice (e.g., Anderson & Shattuck, 2012; McKenney & Reeves, 2012), the two doctoral studies showed the potential advantages of DBR to improve practices through the active involvement of practitioners. Similar to the findings of Kennedy-Clark (2013), the pragmatic nature of DBR enabled the DS1 and DS2 researchers to improve their research design and their un-

derstanding of the problem working with practitioners united by a common purpose. For example, DS1 included both types of research on practice and research in practice concurrently. That is, it involved research on a practice by working with practitioners to design a PD program and used as a springboard to improve their educational practices to improve the practitioners' competencies to use technology in teaching mathematics. This implies that the DBR approach allowed the researchers to work in collaboration with the practitioners to improve practitioners' practical problems designed to enhance their practices rather than only doing research on them. This is also another dimension for doctoral students to use DBR approach in their doctoral dissertation as a research methodology to influence practice as well as creating a long-term partnership with practitioners.

CONCLUSION

In this study, we used Reeves (2006) and Herrington et al.'s (2007) phases and principles of the DBR approach to examine the methodological approaches of two doctoral dissertations. As a result, the authors of this study presented two different doctoral dissertations that have adopted a DBR methodological approach. As evident throughout this study, DBR provides an important methodological approach for understanding and addressing problems of practice, particularly in the educational context, where a long criticism of educational research is that it is often divorced from the reality of the everyday (Design-Based Research Collective, 2003). Doctoral candidates, situated in Faculties and Schools of Education, who adopt a DBR methodological approach are positioned well to begin to change this mantra and to generate authentic change within the educational context.

This study has also demonstrated that the DBR approach can be employed to bring researchers and practitioners together to design context-based solutions to educational problems, which have deep-rooted meaning for practitioners about the relationship between educational theory and practice. As shown in the two doctoral studies, the researchers and practitioners worked closely together, making meaningful changes to their practice. Thinking creatively about what DBR might look like within the doctoral process and encouraging doctoral students to explore the methodological approach is a way to facilitate this notion. The design principles presented in this study can help guide this exploration.

Even though DBR is assumed a long-term and intensive approach to educational inquiry that doctoral students should not attempt to adopt for their doctoral dissertations, the findings of this study demonstrated that DBR can be used in the shorter term and less intensive contexts of doctoral research. The findings of this study could make a contribution to understandings the challenges of using DBR and possible strategies to overcome those challenges to use DBR approach in doctoral work.

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BIOGRAPHIES



Dr Wendy Goff has worked with schools to develop a variety of intervention and support programs targeting the social welfare needs of children and families. Her research focuses on adult relationships and how they might impact on the learning and development of children. Throughout her career she has worked as a social welfare worker, a pre-school teacher, and a primary school teacher. She joined the tertiary setting in 2010. Wendy is particularly interested in the mathematical learning of children, and her recent work involved the implementation of an intervention focusing on adults noticing and supporting the mathematical understandings of children making the transition to school. Wendy uses an Educational Design-Based Research (DBR) methodological approach in her work, and her research is embedded in real-world settings.



Dr Seyum Getenet has worked as a lecturer in Teacher Education University for more than 9 years. He has also taught primary and secondary schools mathematics. His research interest is on pedagogical content knowledge of mathematics teachers and how professional development is used as an enabler for change. Most of his research work use Design-Based Research methodological approach. He is currently working as a Senior Lecturer in Mathematics Curriculum and Pedagogy.